THE Water Research FOUNDATION®

Microplastics in Water

What Are Microplastics?

Microplastics (MPs) are plastic particles under 5 mm in size (but seldom sampled <0.3 mm). They enter the environment through human use. Some plastics are manufactured as MPs; however, larger plastic debris can degrade into micro-sized particles with exposure to sun and water. The appearance and shape of MPs vary widely, making it difficult to quantify and separate MPs from natural particles. Synthetic clothing, plastic bags, polystyrene foam, and disposable plastic can all contribute to microplastic pollution. There are 13 types of MPs—polyethylene, polypropylene, and polystyrene are the most common. There are two primary categories of MPs:

- Microfibers, usually the most common type of microplastics, are derived from synthetic textiles and slough off during daily use and machine washing of clothing (e.g., fleece jackets). Most microfibers released into water are between 0.1–0.8 mm in size. (Hernandez et al. 2017).
- Fragments that form as a result of physical breakage of macroplastics.

Previously, beauty products containing microbeads constituted an additional category of MPs, however, in recent years, many countries have banned/ceased manufacturing these products.

How Bad Is the Problem and What Can We Do About It?

- Microplastics are pervasive in lakes, oceans, and drinking water. Microplastics are ingested, inhaled, or absorbed throughout the food chain, from microscopic organisms to humans (Coffin and Weisberg 2022).

The appearance and shape of microplastics vary widely, making it difficult to quantify and separate them from natural particles.

- Microplastics have been found to adsorb and transport ambient pollutants such as PCBs (coolants), PBDEs (flame retardants), and other persistent organic pollutants.

Can Microplastics Introduce Compounds of Interest and Pathogens to Aquatic Organisms?

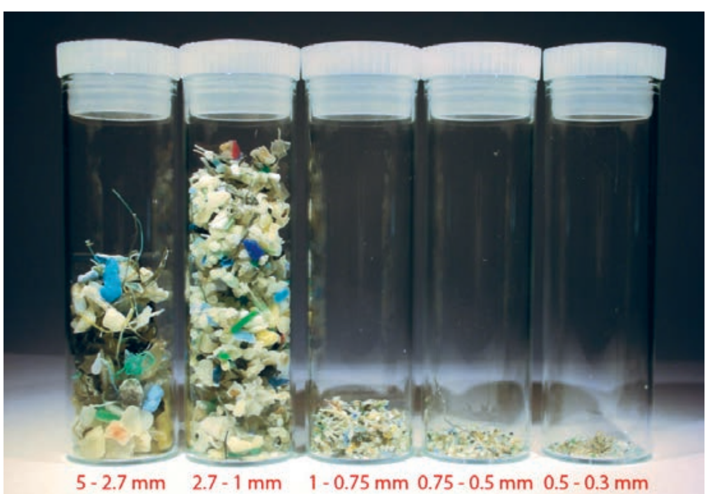
Microfibers have been found in fish and marine animals. However, more research is needed on the toxicology of MPs, including microfibers, and the overall relevance for freshwater resources, drinking water, and human health. A recent study indicated that MPs can act as carriers or "promoters" of antibiotic-resistant bacteria and pathogens (Pham et al. 2021). Since biofilms form on most surfaces in shallow waters, it is likely that pathogens are a component of the biofilms in human-dominated watersheds. The increased availability of nutrients on the particles would increase survival of pathogens, just as in sediments (Burton et al. 1987). This should not pose ecological or human health issues due to low concentrations in comparison to natural sediment particles.

How Are Microplastics Monitored?

The numbers and types of MPs measured vary by method, and often two analytical methods are needed. Monitoring for different types of plastic materials requires advanced instrumentation that is not readily available. This instrumentation may include 1) Raman micro-spectroscopy, 2) Fourier transform infrared spectroscopy (FTIR), 3) focal plane array-based reflection FTIR, 4) combining atomic force microscopy-infrared spectroscopy, 5) field flow fractionation, or 6) optical microscopy. Each method has its own unique strengths and limitations. A few limited studies have tried to quantify the various types of MPs occurring in marine and freshwaters; however, none have allowed for site-specific generalizations. It is difficult to compare MP studies due to lack of standardized methods.

What About Microplastics in Treated Municipal Wastewater and Drinking Water?

Municipal wastewater treatment plants (WWTPs) and water resource recovery facilities (WRRFs) are the largest sources of MPs into aquatic systems in the United States, and likely all developed countries (McCormick et al. 2014). Mason et al. (2016) reported widespread MP pollution from WWTP/WRRF effluents, sampling 17 facilities in the United States. The average discharge was 0.05 ± 0.024 MPs per liter effluent, with a daily discharge of over four million per facility per day. They estimated 3 to 23 billion MPs are released each day by municipal WWTP/WRRFs into U.S. waters. This estimate is less than those cited in prior studies done by Rochman et al. (2015).



Source: Algalita

Size distribution of plastics from a typical Manta trawl

The ability to remove microplastics from water depends on the particle size. A European study found that 90–99% of microplastics were removed in WWTPs/WRRFs, but removal efficiency of smaller particles (20–300 µm) was lower (Browne et al. 2011). A second study found 98% removal of microplastics, though the remaining amount of microplastics discharged to receiving waters was still estimated at 65 million per day (or 0.25 microplastics/L) (Murphy et al. 2016). This demonstrates that when dealing with large volumes of effluent, even a modest concentration of MPs being released per liter of effluent could result in significant amounts of microplastics entering the environment. During conventional wastewater treatment, microplastics are mainly retained by sedimentation. Other research has shown removal by membrane filtration. Larger particles, as investigated in many studies, should presumably be retained during membrane filtration, media filtration, bank filtration, or underground passage (Storck et al. 2015).

Research efforts on MPs in drinking water have been increasing. Water suppliers using surface water supplies impacted by upstream wastewater discharges may have MPs in their raw water prior to treatment, and possibly in their treated water. The traditional size class of 300–5000 µm would not be expected to make it through a modern-day drinking water treatment plant that has filtration.

What Research Has Been Completed?

In 2017, The Water Research Foundation (WRF) published *White Paper – Microplastics in Aquatic Systems: An Assessment of Risk* (Burton 2017), which focused on MPs in the environment and wastewater effluents. The white paper explored the risks of MPs to aquatic systems, analyzed peer-reviewed literature, and identified knowledge gaps.

Burton 2017 found that MPs adsorb some toxic chemicals but are not an exposure route of significance for aquatic birds or aquatic organisms, as compared to prey consumption. Macroplastics are more likely to cause physical harm to fish-eating birds, aquatic mammals and reptiles, and fish. MP concentrations in waters containing the highest number of particles are below 10 particles per 1,000 liters, resulting in very low potential for exposure and uptake by biota. Benthic macroinvertebrates in sediments near WWTP/WRRF outfalls are the most likely receptors to be exposed to potentially adverse levels of MPs. However, improved MP exposure models for effluent discharges into receiving waters are needed to better predict whether MPs may be a stressor of concern. In terms of treatment, WWTPs/WRRFs remove the majority of MPs, with most being captured in sludge. However, in the environment, MP levels are still more likely to be elevated near urban centers and in depositional sediments near municipal WWTP/WRRF outfalls. The white paper suggests a need to conduct realistic exposures to determine ecological risks. Filtration is an optimal treatment for removing MPs from wastewater effluents and intake waters.

In 2022, WRF published *Determining the Fate and Major Removal Mechanisms of Microplastics in Water and Resource Recovery Facilities* (Sturm 2022). The research found that the majority of microplastics are entrained or adsorbed into activated sludge, and developed a standard operating procedure for microplastics sampling and extraction. In the sampling campaign, Nile Red staining enabled sampling several points along eight WRRFs, with a total of 186 filters extracted. In addition, five biosolids samples were extracted. The results of this large sampling effort showed that wastewater influent contained an average 155 ± 178 MPs/L, with 76% of these particles at a size between 25 and 100 µm present as fragment particles. In the biosolids samples, microplastic concentrations varied from 169 to 1844 MP/gram, with an average of 714 ± 665 MPs/gram. The size distribution of microplastics in the biosolids was consistent with the influent wastewater, with 82% of the particles between 25 and 100 µm in size.

Research Gaps and Next Steps

A strategic research plan is needed to address critical knowledge gaps within the next five years. This plan should be conducted in concert with interested federal/national agencies (e.g., EPA, Environment and Climate Change Canada, NOAA, European Chemicals Agency, and Commonwealth Scientific and Industrial Research Organization) and with standard-setting organizations (e.g., American Society for Testing and Materials, International Organization for Standardization, and Organization for Economic Co-Operation and Development). Some of the knowledge gaps are currently being addressed by these agencies and individual researchers, so the strategic plan should describe a process for engaging key parties and stakeholders.

One specific gap that should be investigated is MP measurement and sampling. Measurement methods for MPs vary significantly, and there is no universal protocol for sample preparation, which can make results hard to compare. Standard methods for collecting, identifying, analyzing, and determining toxicity and bioaccumulation are needed.

An ongoing WRF project, *Defining Exposures of Microplastics/Fibers (MPs) in Treated Waters and Wastewaters: Occurrence, Monitoring, and Management Strategies* (Fahrenfeld, forthcoming) will critically review microplastic occurrence data in water, fill in data gaps, provide media-specific sampling and monitoring guidelines, and use water cycle-scale mass balance to inform a decision-making framework for microplastic reduction strategies. Research results are expected in 2024.

In order to properly educate consumers on the implications of microplastics in drinking water and avoid compounding public concern with a paucity of resources and confusing or conflicting messaging, it is essential to conduct proactive research to anticipate and understand these concerns, develop appropriate and accurate responses, and communicate with a consistent voice. *Developing Strategic Consumer Messaging for Microplastics in Drinking Water Supplies* (Alspach, forthcoming) seeks to build the necessary water industry institutional knowledge about the microplastics issues of greatest consumer interest, and proactively generate appropriate messaging to address those concerns in response to inquiries. The research team plans to develop a summary report and educational infographics geared toward consumers.

Research on the fate and transport of microplastics in drinking water treatment facilities is the next logical step to complement the existing MP research portfolio. More research is needed on the removal of MPs by various conventional and advanced drinking water treatment processes; particularly for sizes smaller than 300 microns (0.3 millimeters). A newly funded WRF project, *Fate of Microplastics in Drinking Water Treatment Plants* (WRF, forthcoming), will help utilities operating drinking water treatment plants better understand their current MP removal potential and inform optimization of the treatment process for MP removal.

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